LA-UR-20-23455
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Title: Critical Materials Capabilities at LANL

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Intended for: Briefings and discussions with DOE-EEERE

Issued: 2020-05-07

Critical Materials Capabilities at LANL

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NNSA
National Nuclear Security Administration
Managed by Triad National Security, LLC for the U.S. Department of Energy's NNSA

Bottom Line Up Front

- Critical materials are a recognized problem
  - In addition to being it's own cross-cutting topic area, it is called out in Advanced Energy Storage Initiative, Transportation Sector Priorities, and Energy Efficiency Sector Priorities
    - The need for domestic battery technology is a priority
    - Domestic supply, separations and processing technologies are required to reduce dependence on foreign capabilities
- LANL maintains many capabilities that are applicable to REEs and critical materials
  - Actinide processing capability for defense programs
  - Extensive separation capabilities – trace analysis up to pilot scale
- Development of new approaches for reprocessing technologies are often tested first on lanthanides

LANL excels in many technical areas

Driven by our Capability Pillars:

- Materials for the Future
- Complex Natural and Engineered Systems
- Science of Signatures
- Information Science for Prediction
- Nuclear and Particle Futures

- World leaders
  - Actinide handling and science
  - Computing and predictive science
  - Fuel cells
- Fast Followers
  - Additive manufacturing
- Practitioners
  - Facilities
  - Analytical capabilities

Recognized problem

- However; many different definitions depending on the agency and industry
- DOE produced critical material strategies in 2010 and 2011. Focus was on technologies for clean energy production.
- In July 2017, EO 13806 was issued directing DoD to identify materials & goods critical to national security
- In December, 2017, EO 13817 was issued directing DOI to report on what materials are critical and strategy and options for reducing dependence
- USGS has produced a critical mineral review; and DOI has identified critical minerals
- Different definition and different list for each agency
- In addition to being it's own cross-cutting topic area, Critical Materials are called out in Advanced Energy Storage Initiative, Transportation Sector Priorities, and Energy Efficiency Sector Priorities
  - The need for domestic battery technology is a priority
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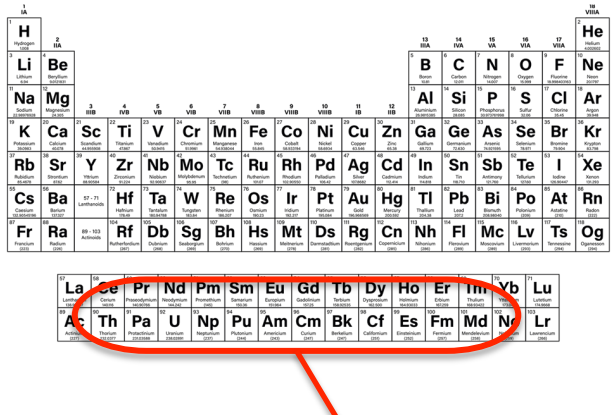
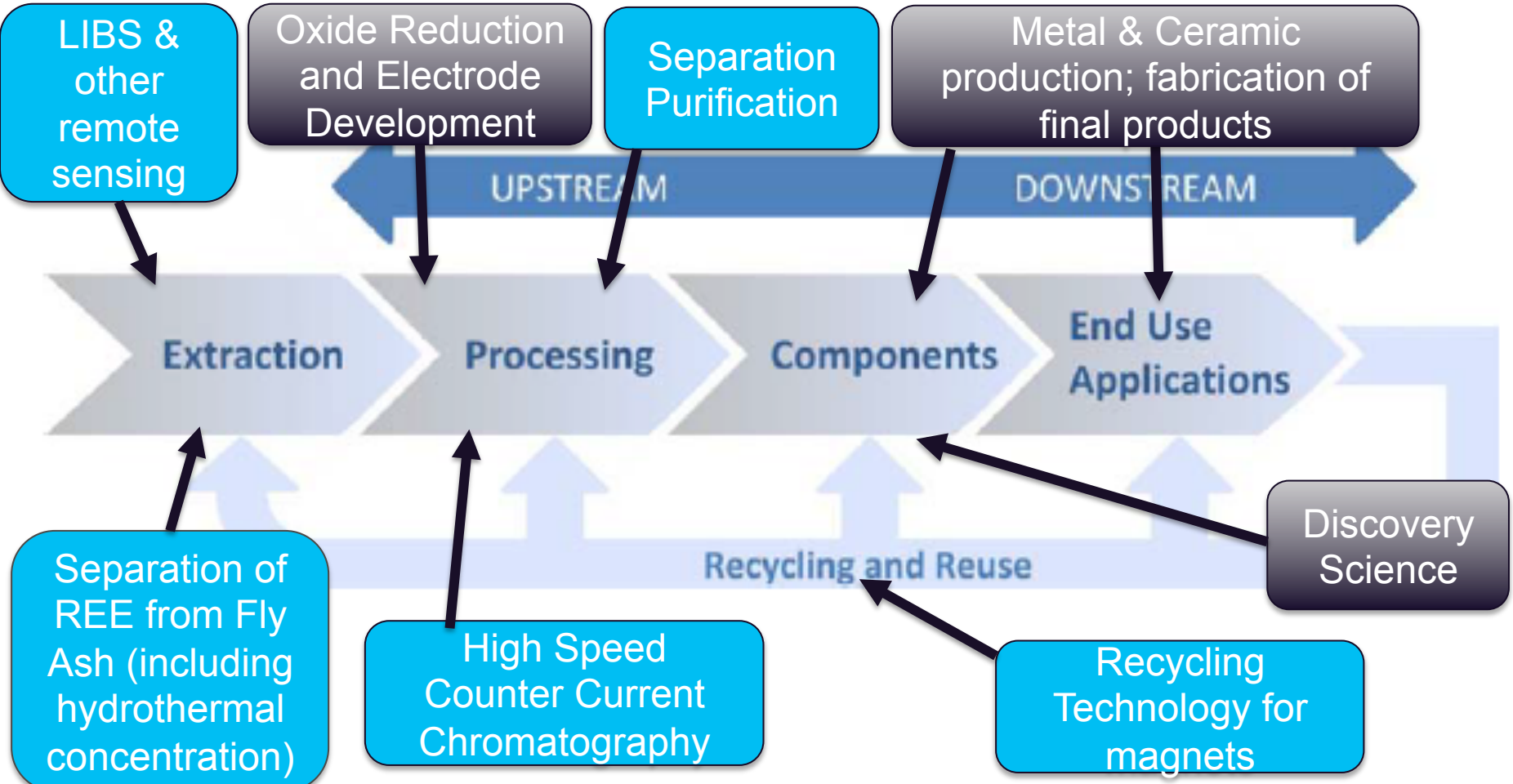
LANL Must Maintain Excellence for our NNSA Mission

- Separations
  - Trace elements for QA and basic analysis
  - “pilot” scale processing
- Purifying and Processing Actinide Materials
  - Separations as well as converting oxide to metal
- Waste Management
  - Managing many “unique” waste streams and providing support to policy makers for long-term solutions to radioactive waste streams



LANL technologies apply to all stages of the REE Supply Chain



LANL Strengths related to REEs

- LANL science spans the spectrum from TRL1 through TRL9 (including **pilot scale** production)
- LANL maintains expertise in **lanthanides** and **actinides** (including f-element chemistry)
- LANL has deep expertise in **separations** including ion exchange, solvent extraction, oxalate precipitation, etc. Trace element up to **pilot scale**
- LANL maintains purification and production capabilities (including alloying) for a variety of radioactive elements including reduction to metallic and ceramic components, fabrication of final assemblies, and management of waste streams
  - Manufacturing capabilities include pits, nuclear fuels (research scale), heat sources, Americium for well logging
- LANL maintains broad capabilities in quantitative analysis from lab-based methods to field based analysis capabilities

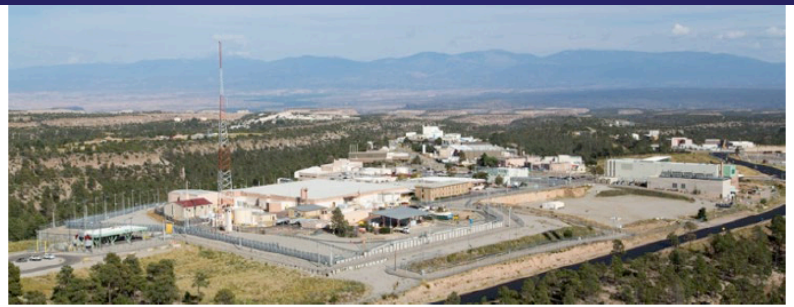
Examples of LANL technologies

1) Aqueous Recovery of Pu
2) Separation of REEs from Fly Ash
3) Magnet recycling technology development
4) Remote sensing technologies for REEs

What else we do:

- Ligand development
- Electrode development
- Battery development
- Trace separations
- Nuclear fuels – including ceramics
- Fundamental research (e.g. single molecule magnets, superconductors, scintillators, etc)
- Technology transfer

Example 1: Aqueous Recovery of Pu for pit production



Plutonium Oxide

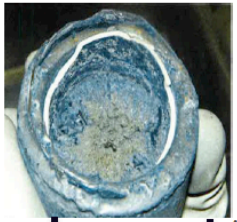
Plutonium Metal

Plutonium Core (Pit)

Multi-Cycle Direct Oxide Reduction → Metal Chlorination → Electrorefining → Casting → Machining → Welding

DOR salt

MSE salt



ER salt

Anode heel

Casting skull

Mixed turnings

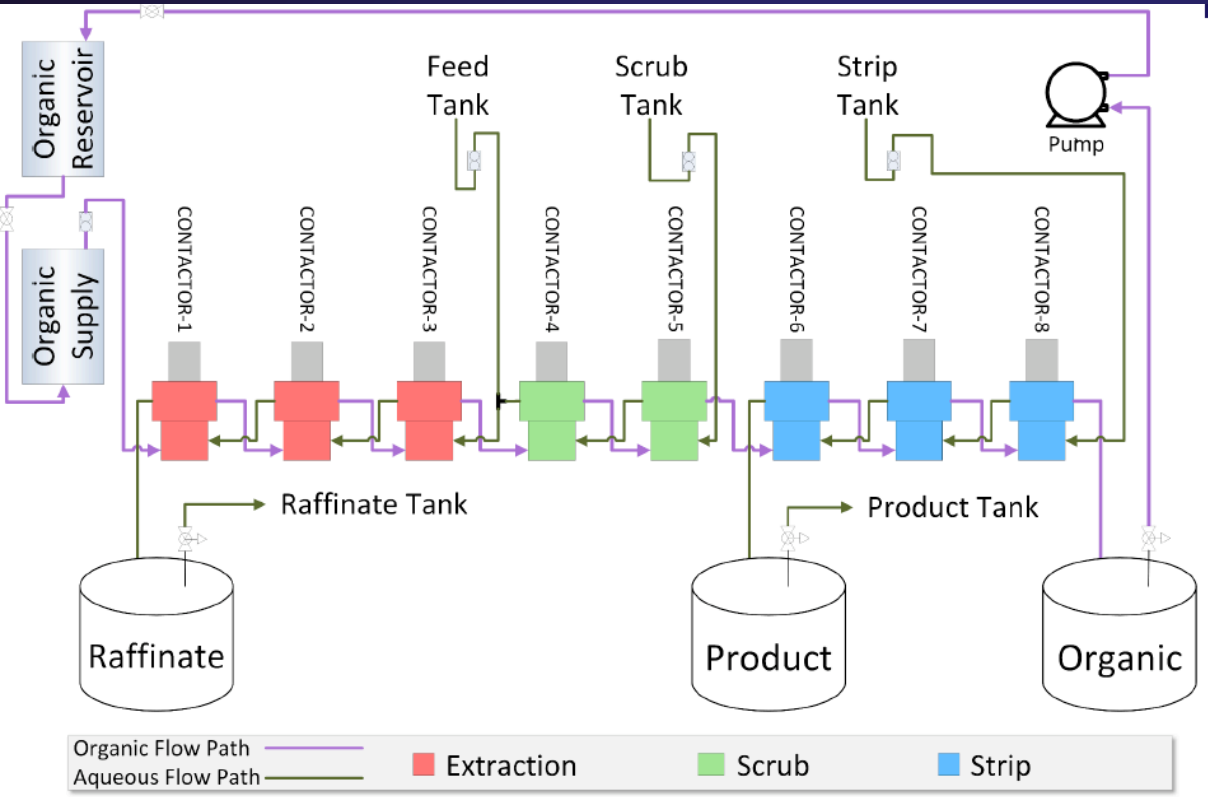
Aqueous Chloride Recovery Line

Aqueous Nitrate Recovery Line

In addition, New methods are being evaluated to improve efficiency and safety of process

Aqueous Operations in PF-4; LAUR-19-30788

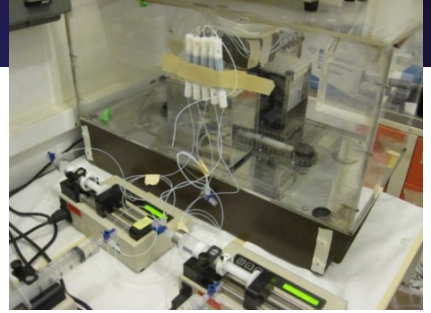
Solvent Extraction



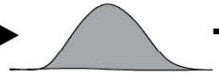
- Feed: 5-7 M HCl with impure Pu (sodium chlorite oxidant)
- Scrub: 6 M HCl (clean)
- Strip: 0.1 M HCl
- Organic: 70% dodecane, 20% TBP, 10% n-decanol by volume

Aqueous Operations in PF-4; LAUR-19-30788

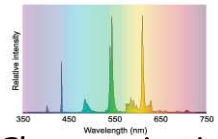
Example 2:Separation of REEs from Fly Ash



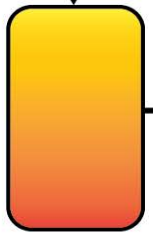
Detroit Coal Power Plant



Coal or fly ash with REEs



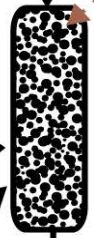
Characterization (WSU)



Hydro-thermal extraction (LANL)

Supernatant with REEs

Osorb-ligand optimization (WSU)



Loading of REEs on Ligand-Osorb packed columns (WSU)

REE-free solution

Strong Acid

Concentrated REEs

Leaching of REEs from Ligand-Osorb packed columns (WSU)

Optimization of sorption/desorption of REE from ligands (UCLA)

Evaluation of Novel Strategies and Processes for Separation of Rare--Earth Elements from Coal
LAUR-19-27898

Hydrothermal Extraction Proof of Principle

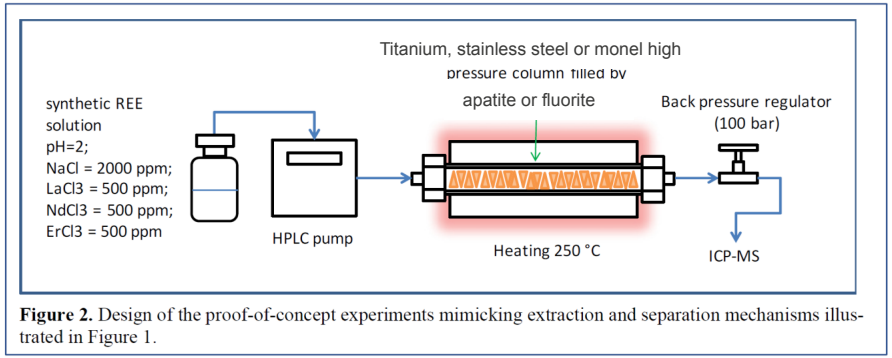
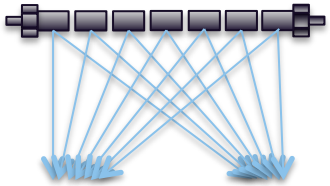


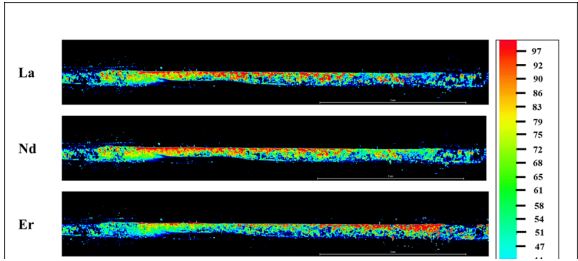
Figure 2. Design of the proof-of-concept experiments mimicking extraction and separation mechanisms illustrated in Figure 1.

Post-experiment treatment

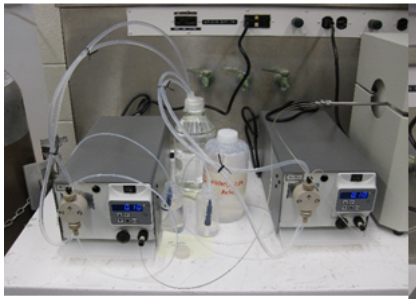


XRD
(mineral composition)

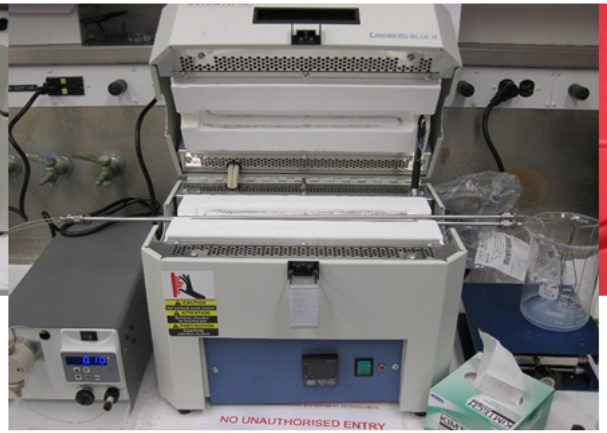
XRF
(chemical composition)



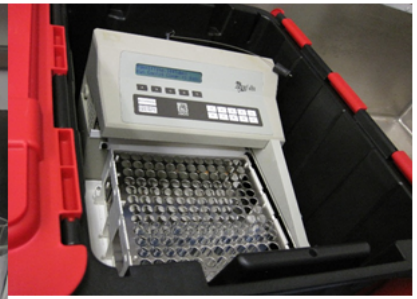
XRF map of REE / concentration separation along the column length



High Pressure Pumps



Oven



Fraction collector

Evaluation of Novel Strategies and Processes for Separation of Rare--Earth Elements from Coal
LAUR-19-27898

Example 3: Recycling Technology Development

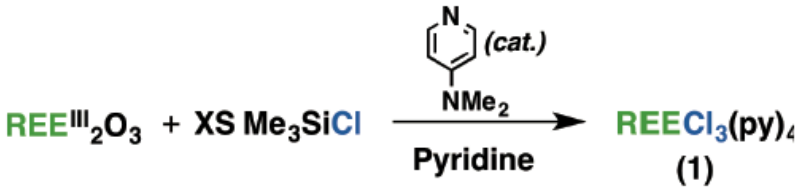
- Magnet scrap REEs can be oxidized using trimethylsilyl chloride in pyridine while transition metals remain undissolved (Technology 1)
- Deoxygenation of the REE sesequeoxides using trimethyl chloride to form trivalent REE chloride complexes enabling effective separations of light and heavy REEs

Element	Sc	Y	Ce	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Separation Factor	500	250	150	89	490	490	980	490	160	98	140

Technology #1

REE = Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Tm, Yb, Lu

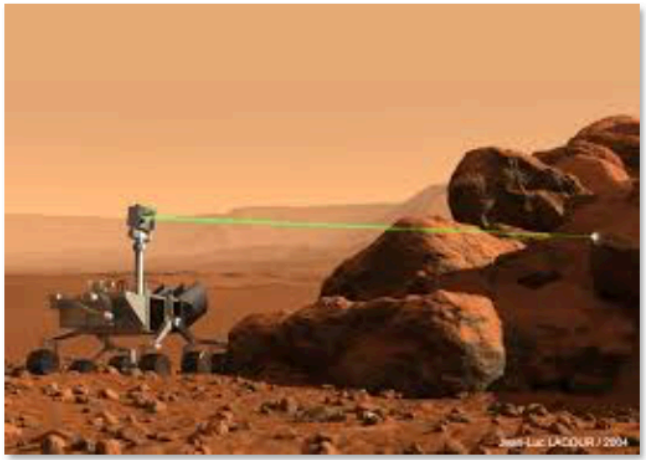
Technology #2



REE = La, Pr, Nd, Sm, Eu

Extraction of Rare Earth Elements from Magnets and Magnet Waste Streams; LAUR-19-32623

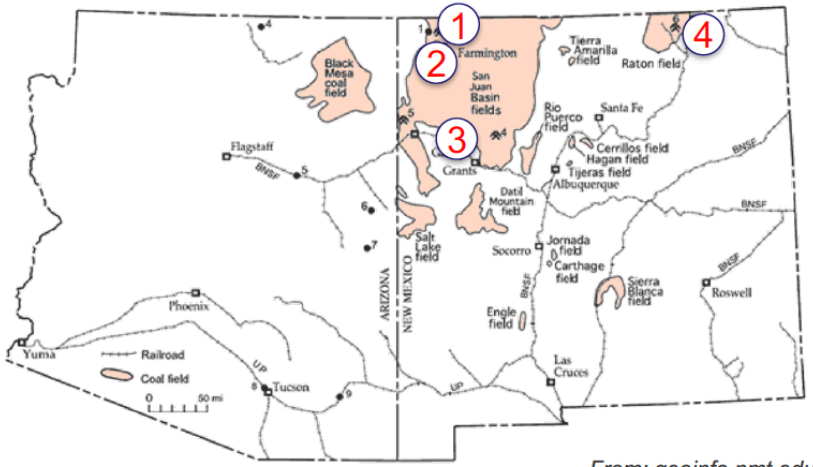
Example 4: Remote sensing of REE based on LIBS & Raman



From: nasa.gov

- Long history of LIBS development for core mission needs
- Institutional investments (including recent LDRD for LIBS+Raman)
- Field unit development for DOE-FE (carbon) (R&D100 Award)
- One unit on current Mars mission; new unit on future Mars mission

Laser-Based Analysis of Rare Earth Elements in Coal-Related Materials
LAUR-18-21485



From: geoinfo.nmt.edu

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Questions?